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SYNOPTIC CLIMATOLOGY OF STAGNATING ANTICYCLONES EAST OF THE ROCKY MOUNTAINS IN THE UNITED STATES FOR THE PERIOD 1936-1956

Julius Korshover

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1960

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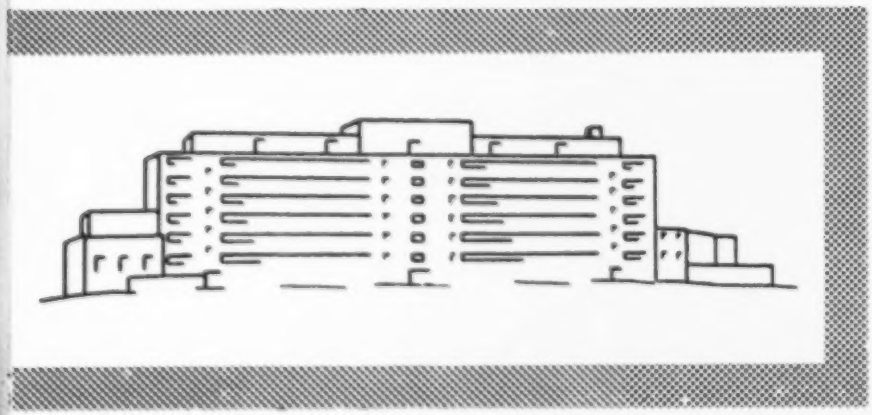
East Of The Rocky Mountains In The United States For The Period 1936-1956



The Robert A. Taft
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TECHNICAL REPORT
A60-7

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JULIUS KORSHOVER

Special Projects Section
Office of Meteorological Research
Weather Bureau
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Bureau of State Services
Division of Engineering Services

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NOTE

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SYNOPTIC CLIMATOLOGY OF STAGNATING ANTICYCLONES EAST OF THE ROCKY MOUNTAINS IN THE UNITED STATES FOR THE PERIOD 1936-1956

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Office of Meteorological Research
U. S. Weather Bureau
Washington, D. C.

October 1957

INTRODUCTION

The purpose of this study is to define the synoptic climatology of stagnating high pressure systems in the eastern part of the United States. As a first step, it is necessary to make a survey of the location and frequency of occurrence of stagnating anticyclones in the area.

In recent years, due to an increase in urban living, the air pollution problem has become more and more aggravating and has attracted considerable attention. Our gradually increasing population and the concentration of heavy industries in relatively congested areas of population indicate the need for an investigation of the synoptic climatology of this phenomenon with a view to preventing its harmful effects upon human life in the future.

It has been observed that major air pollution episodes are usually related to the incidence of stagnating anticyclones in or near urban areas. Such anticyclones usually linger over an area for a protracted period (4 d. s or more). During this period, surface wind speeds may fall to very low values. Surface circulation is therefore insufficient to diffuse the accumulated pollutants of the local atmosphere, thereby causing distressful and possibly hazardous conditions for the inhabitants of that area.

THE PRESSURE GRADIENT METHOD

There are few studies of air pollution climatology on record. After considerable preliminary experimentation, it was decided to employ a pressure gradient technique for determining the occurrence of cases of stagnation. This procedure is desirable because the pressure gradient gives a more representative picture of the general flow near the surface of the earth than do individual surface wind measurements. Willett evaluated the significant surface wind during the extreme smog development at Donora, Pennsylvania, in October 1948. At no time during a four day period was the maximum surface wind greater than 8 mph. (1) In this study, therefore, the limiting wind speed taken at anemometer level is assumed to be 7.5 knots. The authors of Dynamic Meteorology and Weather Forecasting show (in Table 12.35.1) the ratio between the surface wind and the geostrophic wind speed. At 30°N latitude over land, this ratio is 0.31 and at 40°N latitude, the value is 0.36. (2) Willett maintains that the surface winds are observed to average about 2/3 of the gradient wind speed. (3) Brunt states that the surface wind should be about 0.7 times the geostrophic value for light winds. (4) In this study, the value of 0.5 has been adopted as the ratio between the surface wind and the geostrophic wind speed. Usually the difference between geostrophic and the gradient wind speed is small and for this reason these two terms have been used interchangeably by many authorities. As added confirmation for the 15 knot geostrophic value, J. J. George found that the average maximum gradient (geostrophic) wind speed which allows the formation of fog is close to 15.0 mph. (5)

METHOD AND PROCEDURES

All the apparent stagnant anticyclones that have occurred between 1936-1956 east of the Rocky Mountains were selected for this study. The following procedures were used in determining cases of stagnation with the pressure gradient method.

Step 1. The United States Weather Bureau Daily Map (6) containing a synoptic sea level analysis was used exclusively to determine the pressure gradient. Prior to 1936, available upper air information was sparse and inconclusive. The period of this survey extends for only twenty-one years, 1936-1956.

1. The author is grateful to Dr. Lester Machta, Fred D. White, Dr. James K. Angell, and Donald H. Pack for their many suggestions and constructive criticism.

A list of all anticyclones which showed a possibility of stagnation for four days or more were recorded. These cases were carefully checked to determine whether portions of areas of stagnation as defined below overlapped for periods of four days or more. In Figure 1, the technique for determining stagnant areas is shown. In this figure, the effect of latitude on the geostrophic wind is not considered and, therefore, the geostrophic wind is constant for a given pressure gradient. At each 5 degrees of latitude from 27.5 to 47.5, the pressure gradient corresponding to a 15 knot geostrophic wind was determined. We find that in the isobaric channel ST, the geostrophic wind changes from more than 15 knots to less than 15 knots at points C and D, with the stronger winds to the northeast. In the isobaric channel RS, the geostrophic wind speed is everywhere more than 15 knots. Therefore, the dotted curve delineating the area of stagnation, as defined above, is drawn coincident with the isobar approximately up to the points C and D. Within the isobar T the geostrophic wind is everywhere less than 15 knots. Therefore, the dotted curve delineates the area of stagnation as drawn coincident with the isobar T approximately up to the points C and D. The dashed line is "faired-in" across the isobaric channel at points C and D. The region enclosed by the dotted line, A C E F D B A represents the area of stagnation.

Step 2. The United States from the Rocky Mountains to the East Coast was divided into a set of grid points at every 2^{0} of latitude and 2^{0} of longitude. (See Figure 2) An overlay pattern was then used to facilitate the locating of those grid points which lay within stagnant areas. The grid points of the "squares" thus located were then numbered for identification purposes. The daily records of areas of stagnation were recorded by means of these points on a worksheet. It was then possible to read off areas of stagnation for 4, 5, 6 and 7 or more consecutive days.

Step 3. Wherever frontal areas overlapped areas of apparent stagnation, the latter were excluded because of changing air masses, cloudiness, wind speed, etc.

Step 4. Areas of precipitation were excluded because of the cleansing properties of precipitation.

Step 5. It was discovered that only warm highs meet the criteria for stagnation conditions, since cold highs are not sufficiently persistent. Warm anticyclones are deep, stagnant systems, and high pressure prevails far up into the troposphere and may extend into the stratosphere. Each case was checked for either a trough or ridge in the area of interest at approximately 10,000 feet.

SUMMARY OF RESULTS

Table I is a chronological tabulation of all cases of stagnation. Because of the rather strict criteria used here, some cases may be ignored that might have resulted in potentially serious pollution situations.

In Figure 3, the upper values (above each grid point) are the total number of stagnation cases (4 or more days) and the lower values are the total number of days of stagnation. Dashed isopleths show the distribution of the number of stagnation cases; the solid isopleths the distribution of the number of days of stagnation. They are both similarly distributed. This chart shows the strong influence of the Bermuda High on the east coast. A maximum frequency in both the number of cases and the number of days stagnation occurs in an area which covers parts of Georgia, South Carolina and North Carolina. This region is frequently dominated by the western extension of this semi-permanent high pressure area.

Figure 4 shows the geographical distribution of annual occurrence of cases of stagnation for seven or more days. The values given are the total for the entire twenty-one year period, 1936-1956. This can be compared with Figure 3, the total annual number of stagnation cases for four or more days (dashed isopleths).

A monthly distribution of the number of cases of stagnation for 4, 5, 6, or 7 or more days and the total number of days of stagnation by months are given in Table II.

Figure 5 depicts the distribution by months of the number of cases of stagnation for 4, 5, 6 and 7 or more days. This figure illustrates Table II graphically. The primary peak for four or more days occurred in October with a secondary maximum in June. The percentage distribution by months of cases of stagnation for four or more days is also shown in Figure 5. Table III presents these data in numerical form.

A geographical distribution of four or more days of stagnation by months is given in Figures 6A through 6L. Each month was analyzed and isopleths of equal numbers of cases were drawn. The four months with the most frequent cases of stagnation were May, September, October and November. In May, ten cases of stagnation existed over South Carolina. In September, the maximum number of cases, ten, occurred in Pennsylvania, near 40^{0}N and 75^{0}W, with a secondary maximum, six cases over northern Alabama. In October 15 cases existed over northeast Georgia; eight cases of stagnation occurred in central South Carolina during the month of November. Wexler (7) also finds October to be the month most favorable for the occurrence of deep anticyclones and hazardous smog episodes. Klein (8) depicts the number of different highs for 5^{0} squares for each calendar month during twenty selected years of the original Historical Map Series, 1904-1914 and 1924-1937. In Klein's paper, charts 21-23 for September, October and November are somewhat similar to Figures 6-I, 6-J and 6-K shown here, but with centers of maximum

frequency displaced somewhat northward. He also gives the number of days with highs (both migratory and stationary) during the 40 years from 1899-1939. September and October apparently are crucial months when stagnation is most likely to occur.

Therefore, in this preliminary study, having determined the location and frequency of stagnation anticyclones in Eastern United States, the next step would appear to be a study of the stability of the atmosphere in such situations, and such a study is planned.

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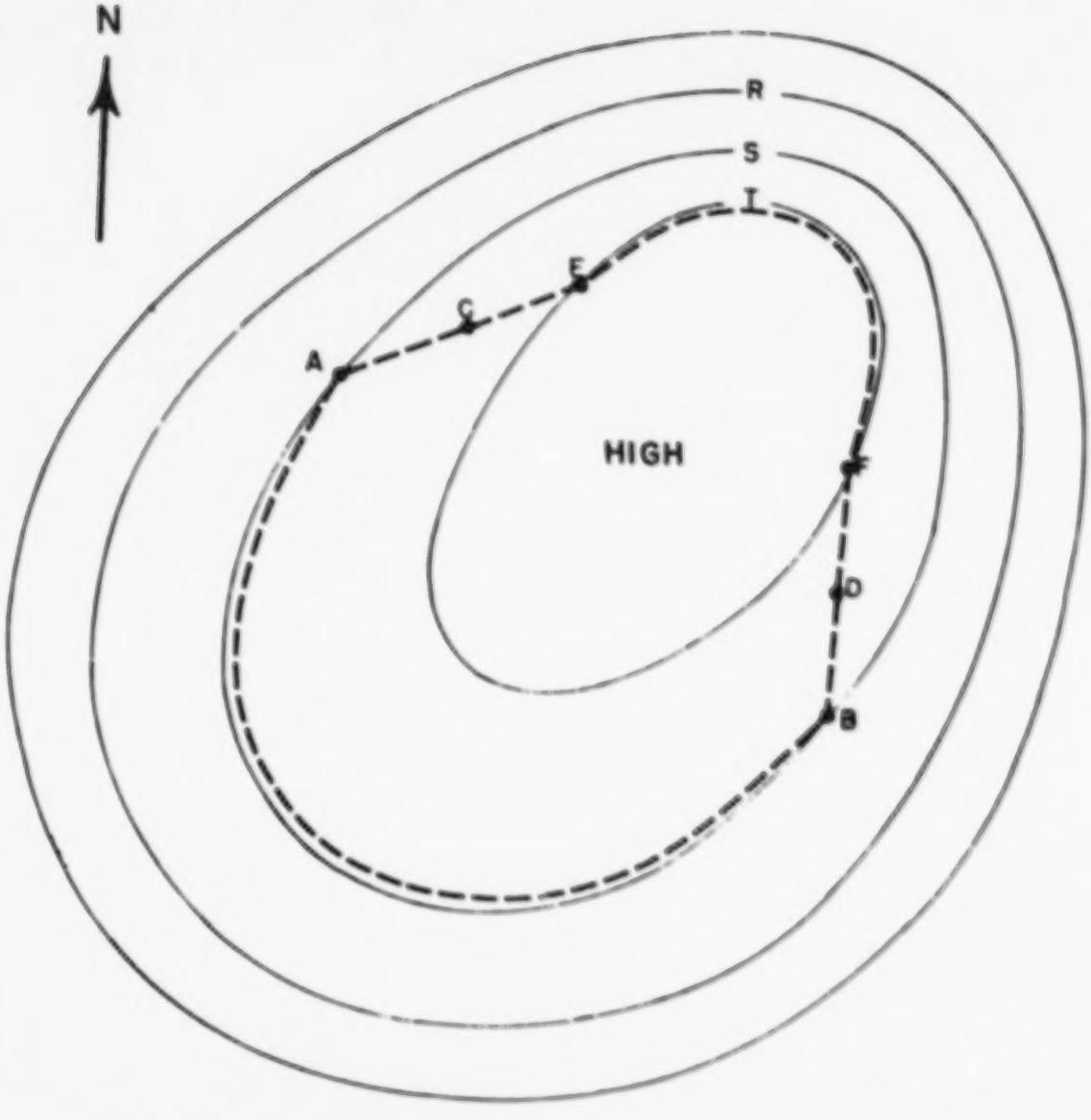

Figure 1
Schematic Illustration of technique for determining stagnation areas

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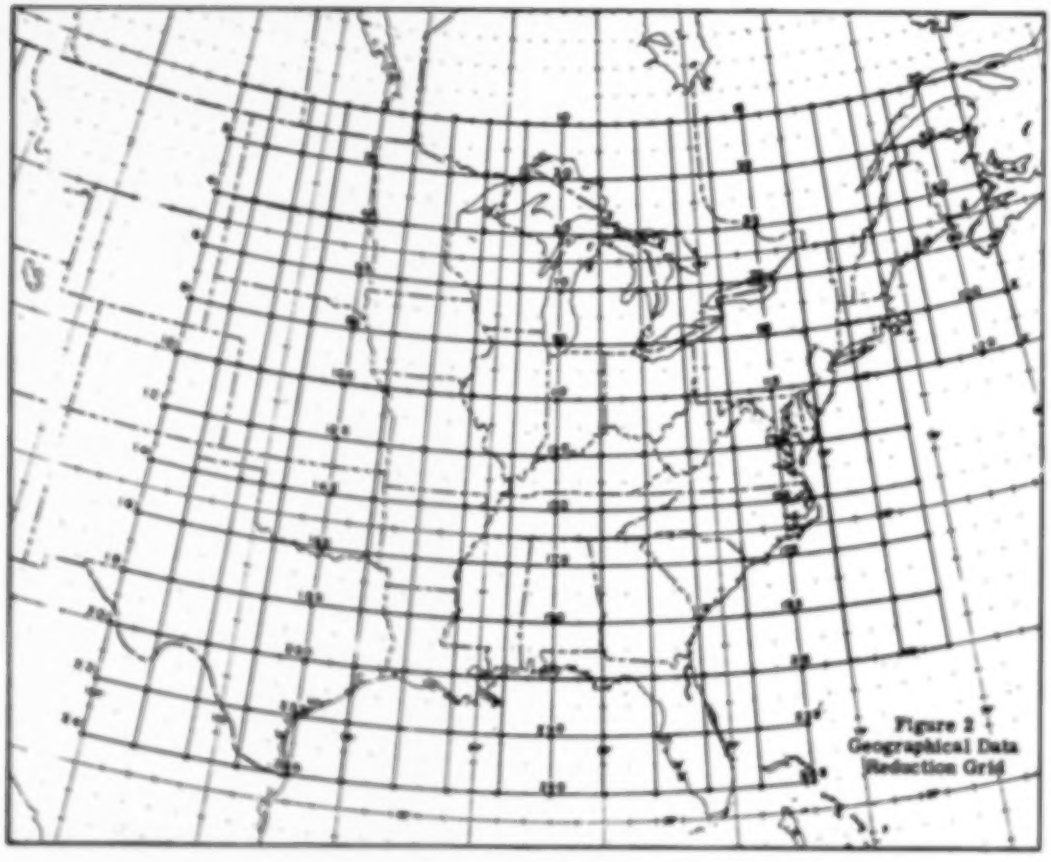

Figure 2
Geographical Data Reduction Grid

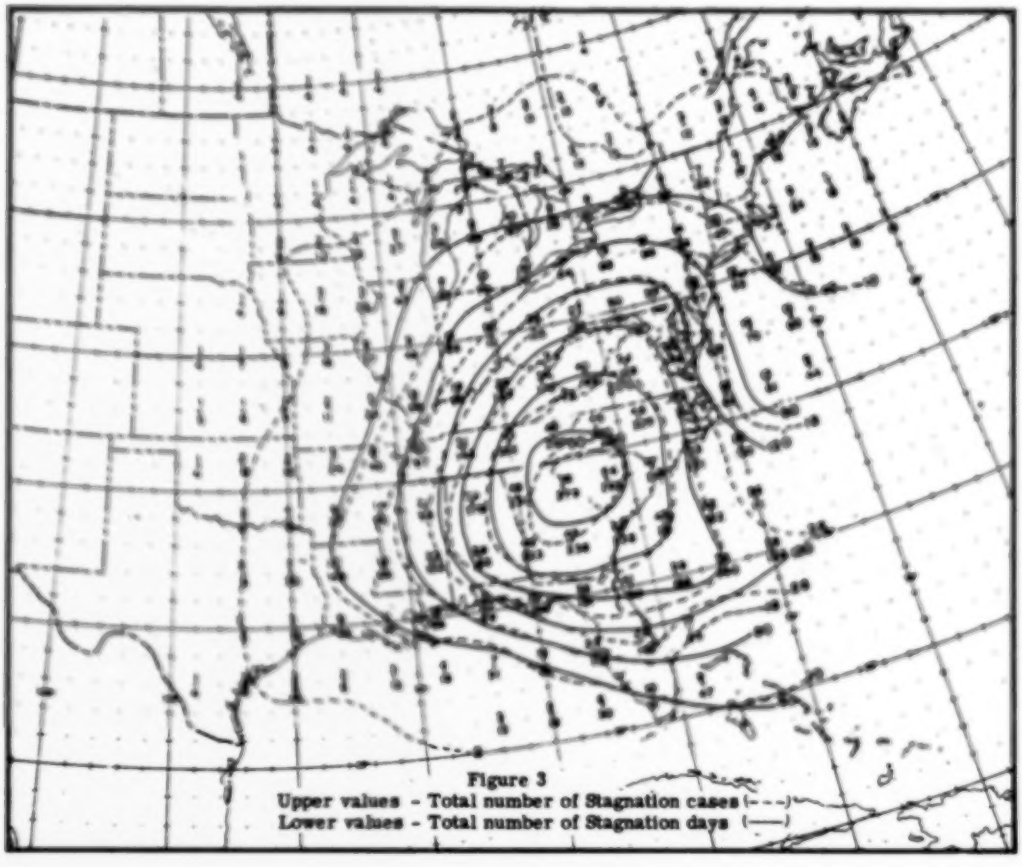

Figure 3
Upper values - Total number of Stagnation cases (- - -)
Lower values - Total number of Stagnation days (——)

Figure 4
Total Annual Number
of Stagnation Cases
(7 or more days)
1936-1950

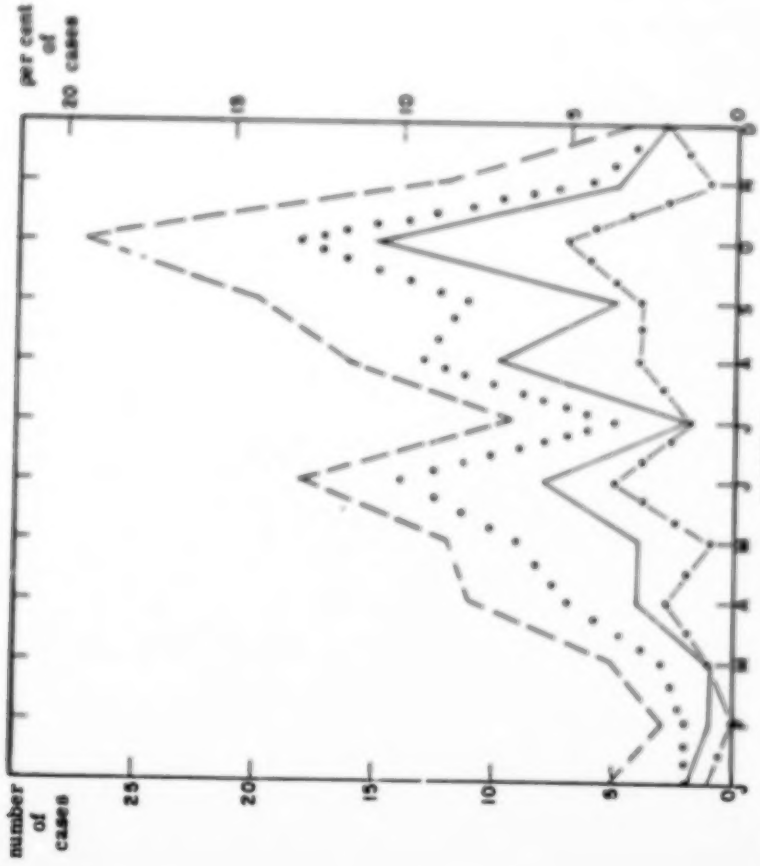

Figure 5
Number of Stagnation Cases for 4, 5, 6, and 7 or more days by month in the United States, east of the Rocky Mountains, 1936-1950.

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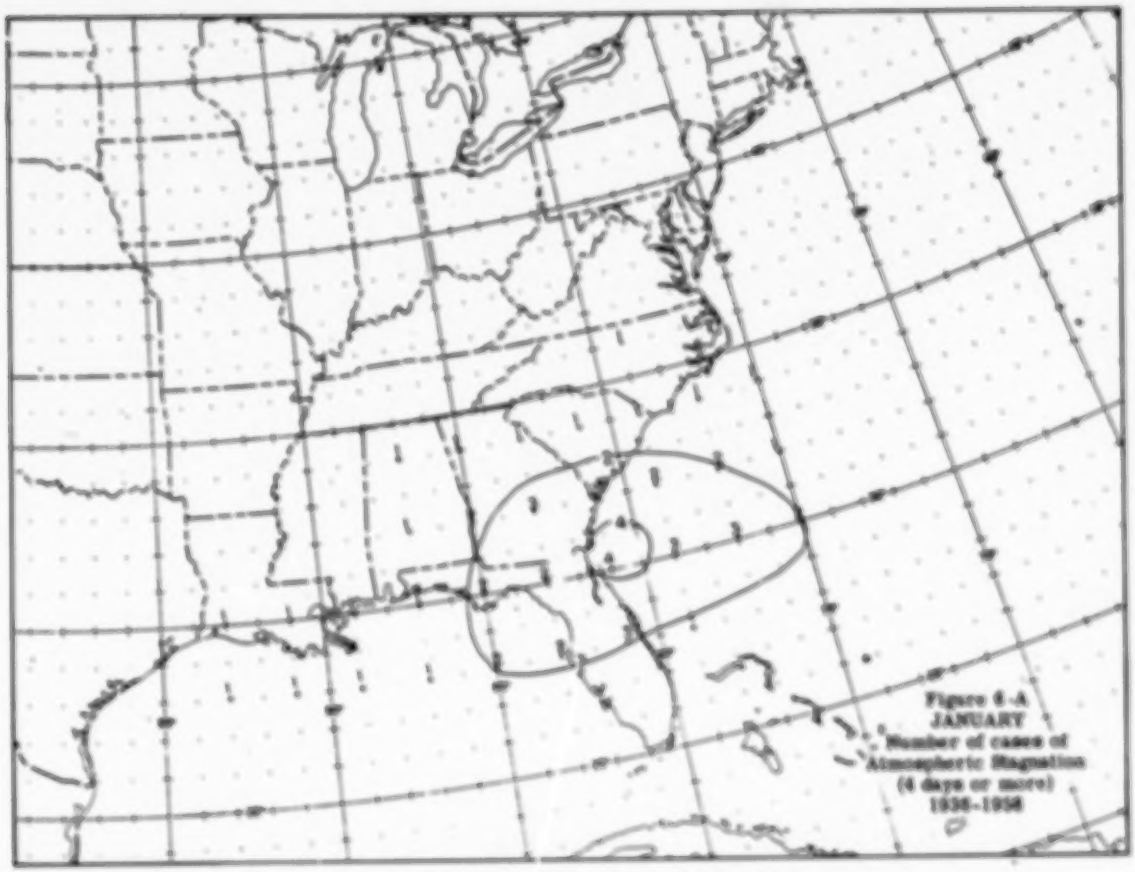

Figure 6-A
JANUARY
Number of cases of
Atmospheric Stagnation
(4 days or more)
1936-1958

Figure 6-B
FEBRUARY

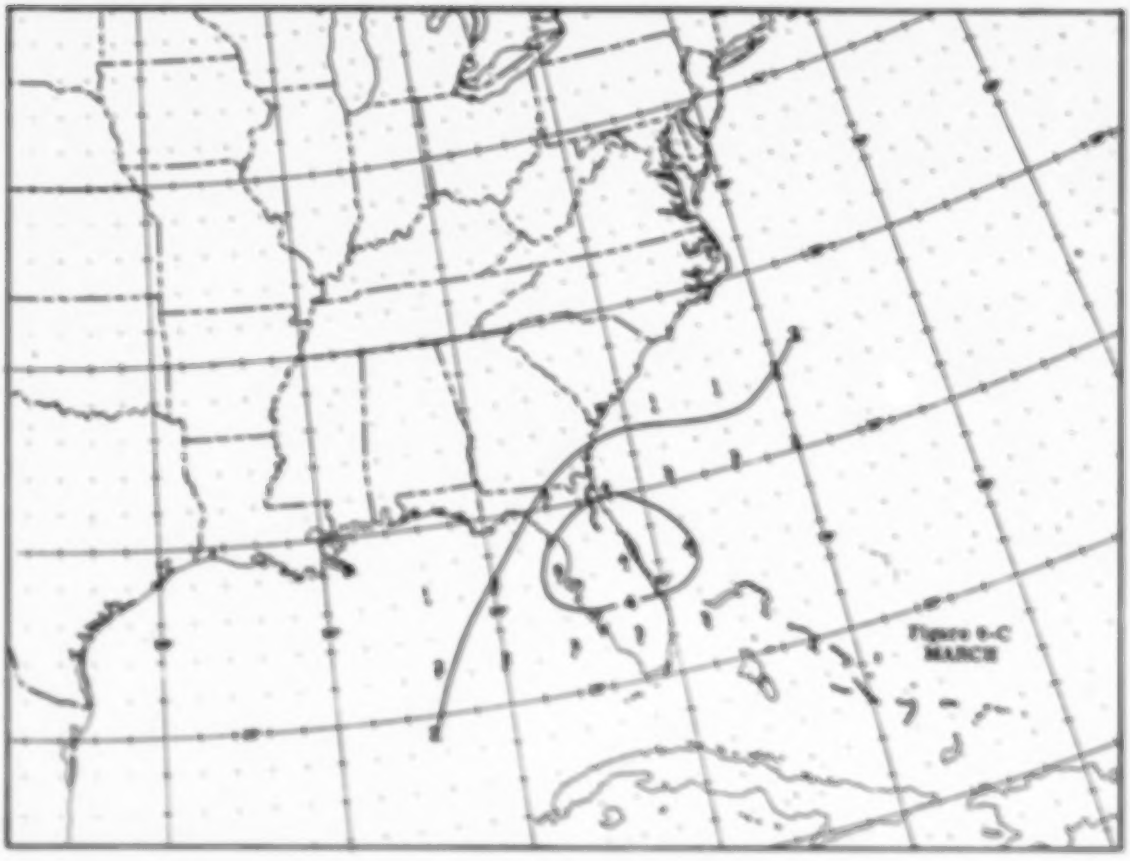

Figure 6-C
MARCH

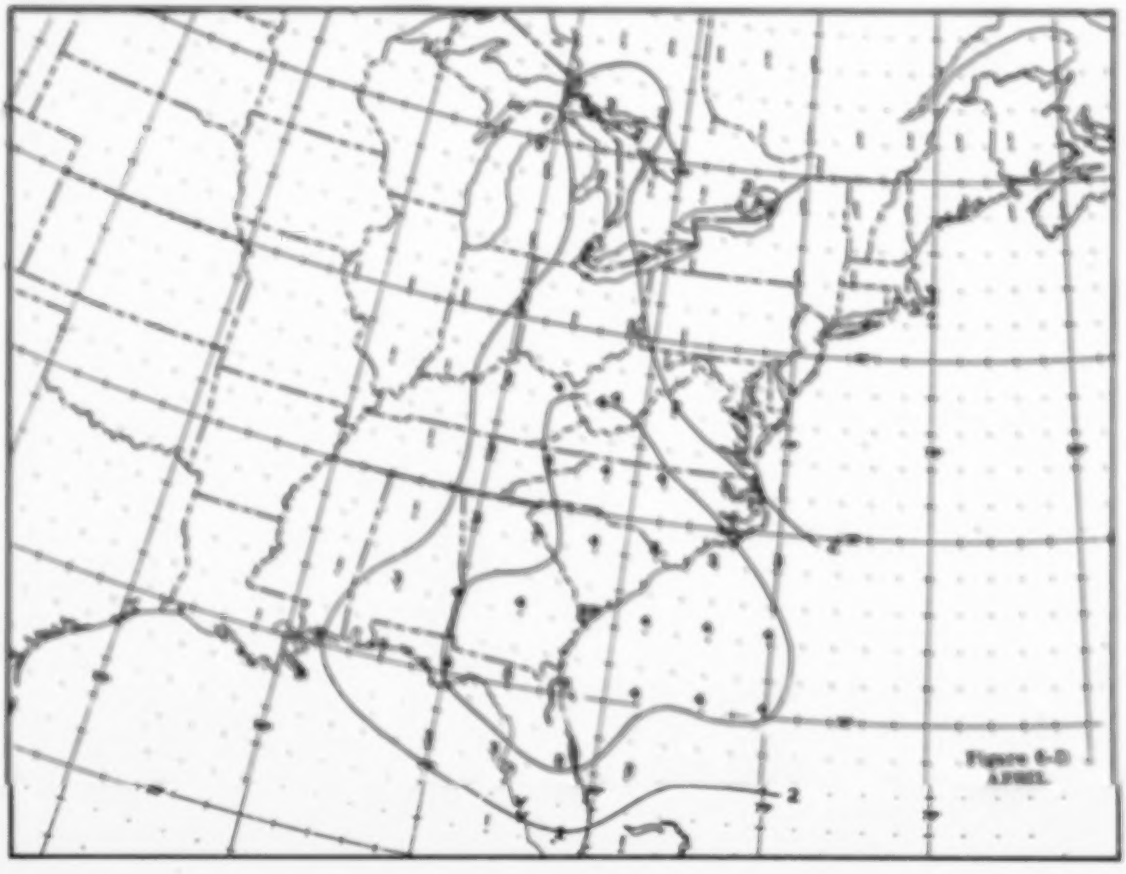

Figure 6-D
APRIL

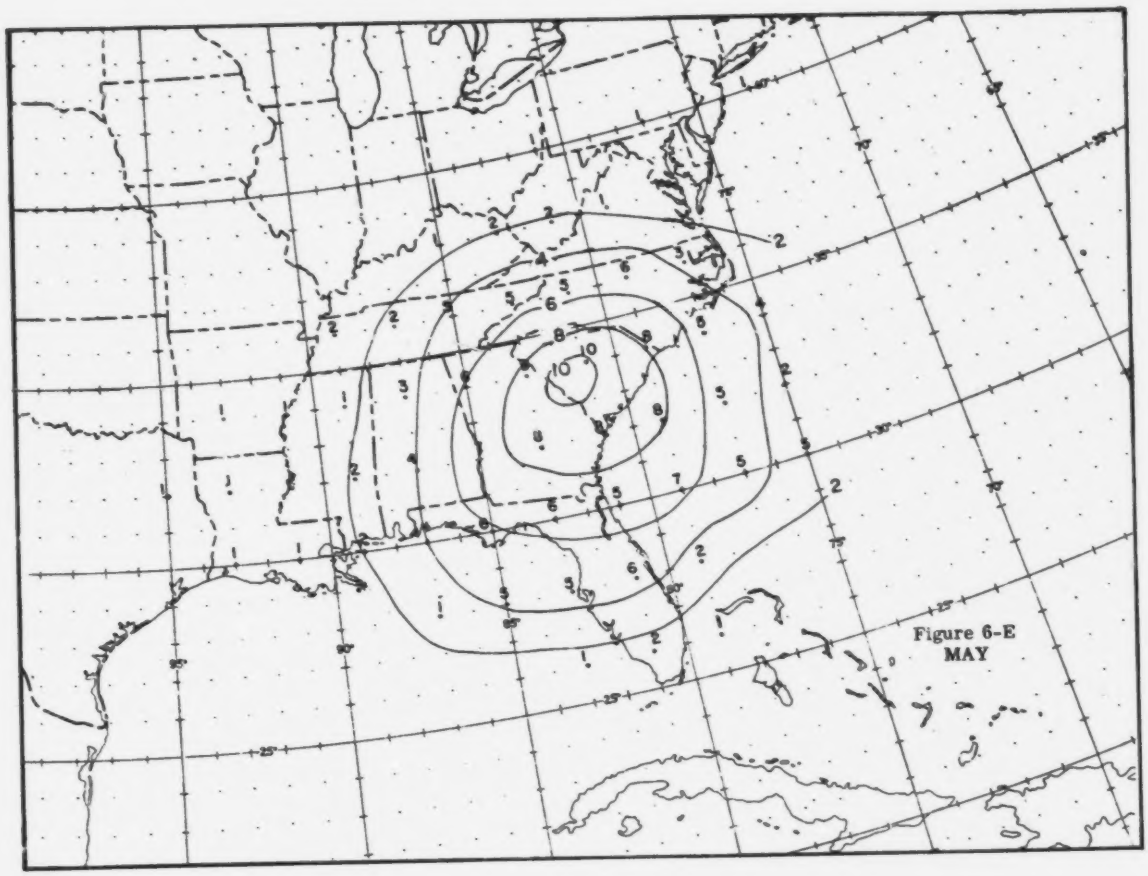

Figure 6-E
MAY

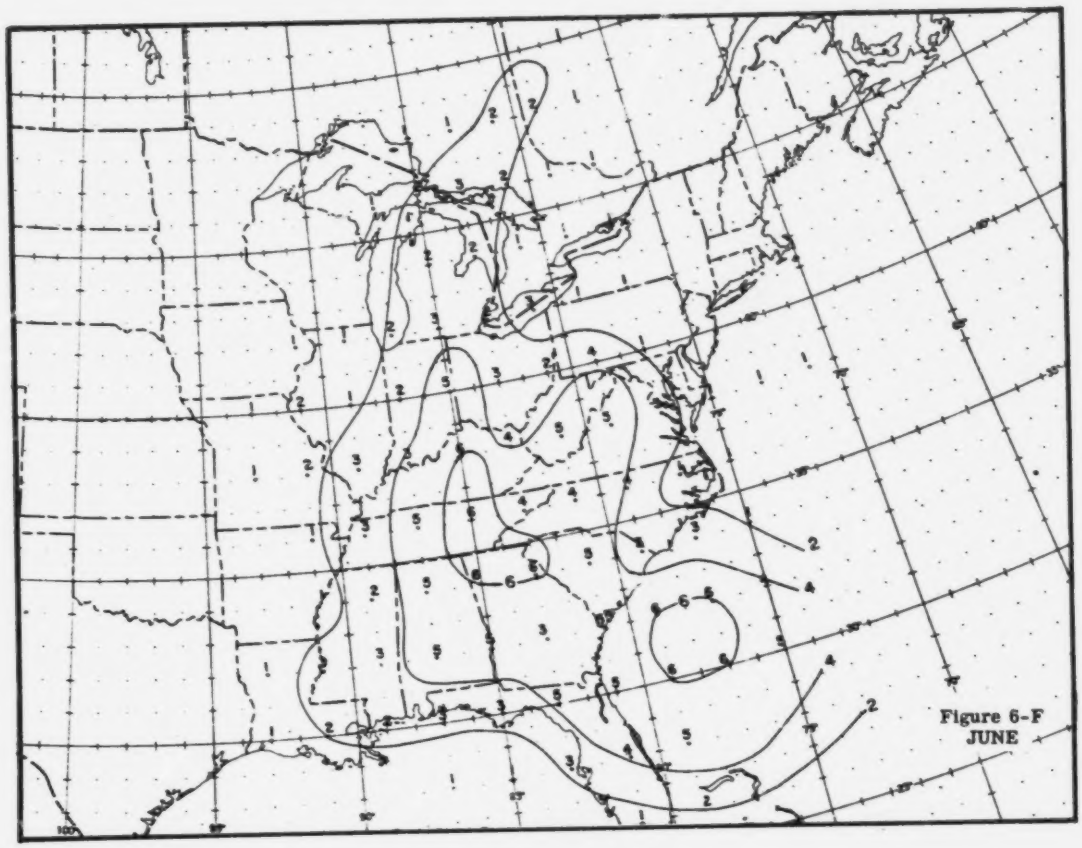

Figure 6-F
JUNE

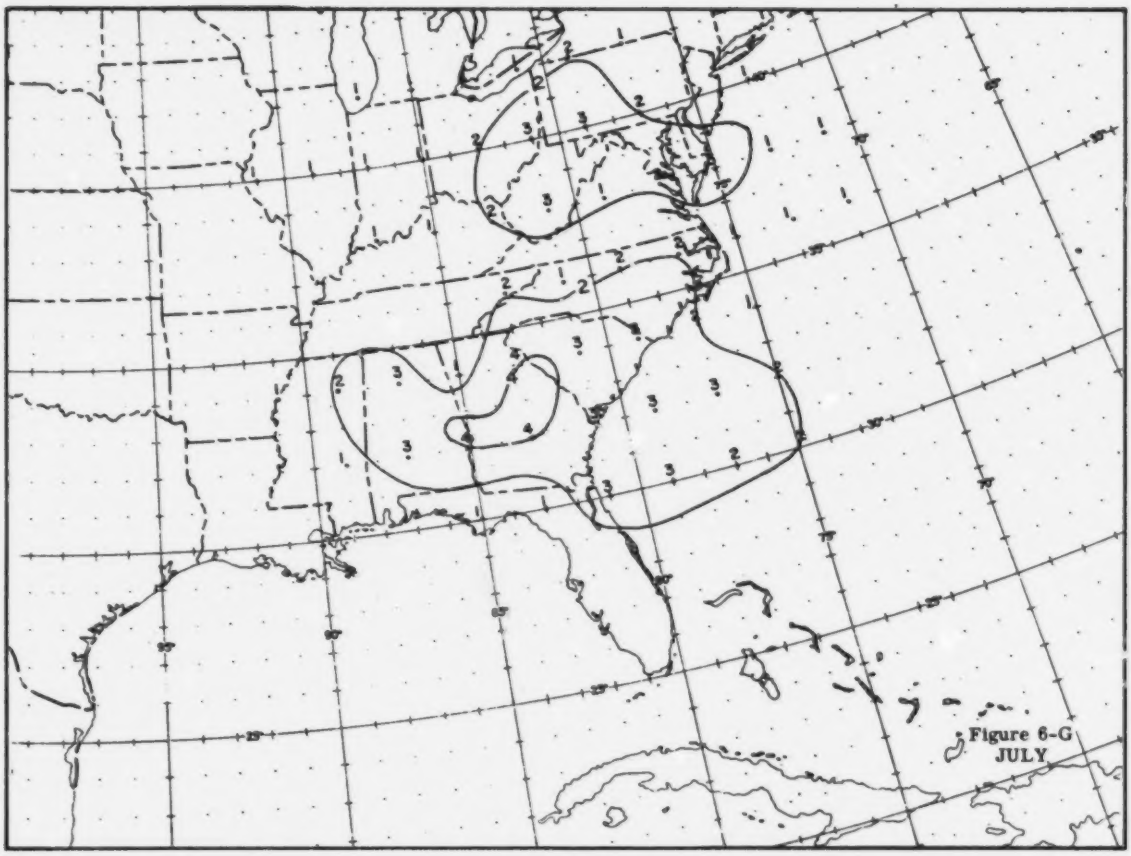

Figure 6-G
JULY

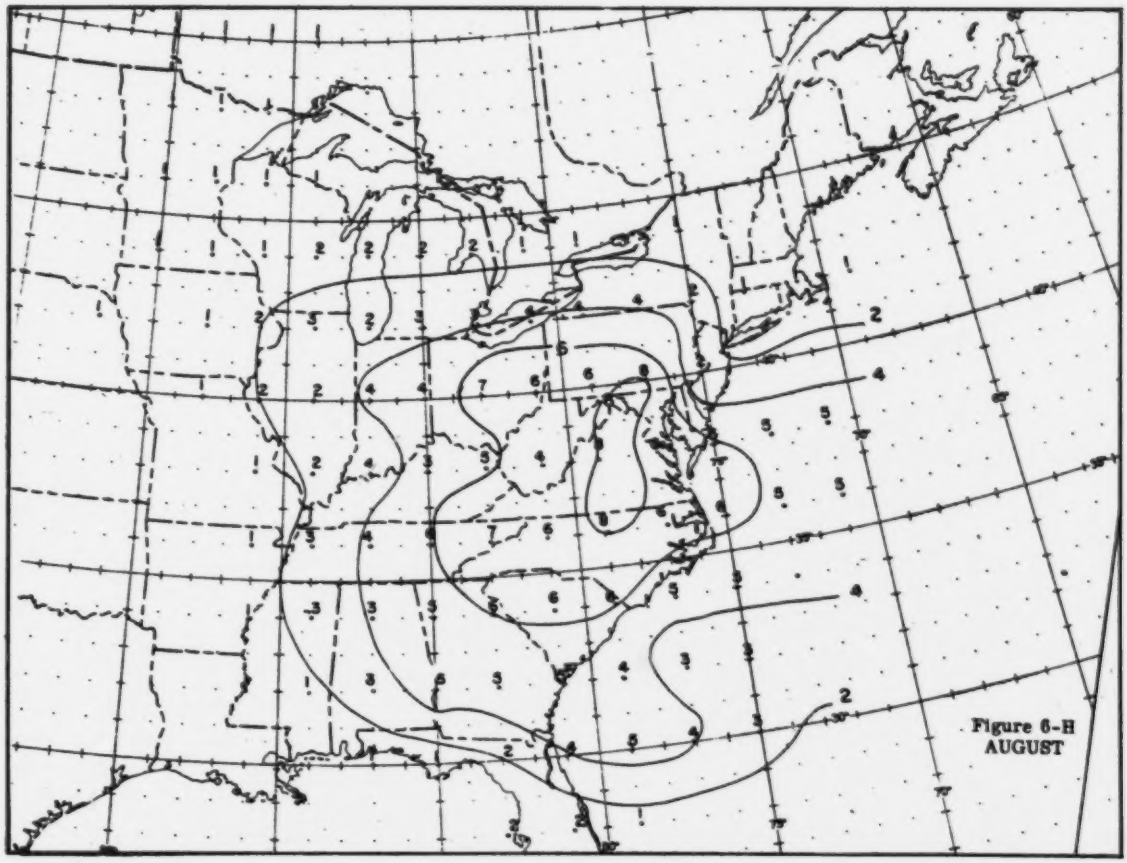

Figure 6-H
AUGUST

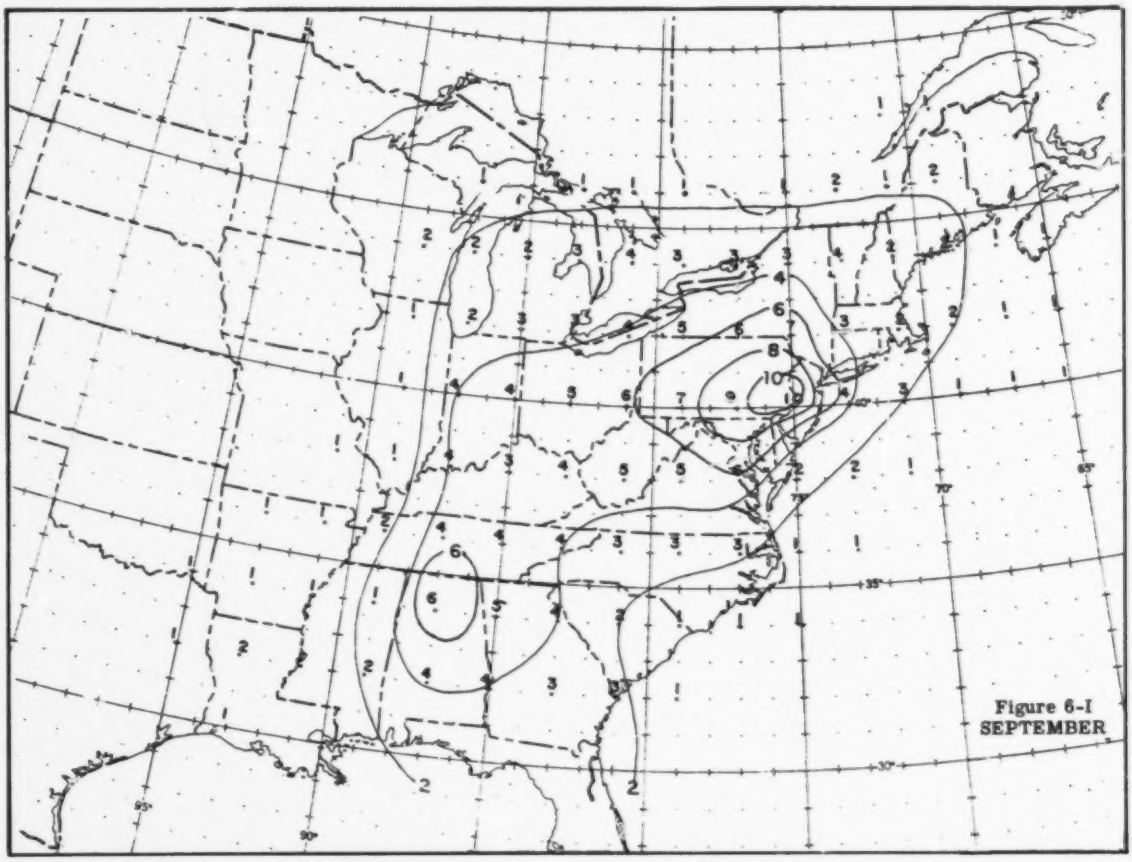

Figure 6-I
SEPTEMBER

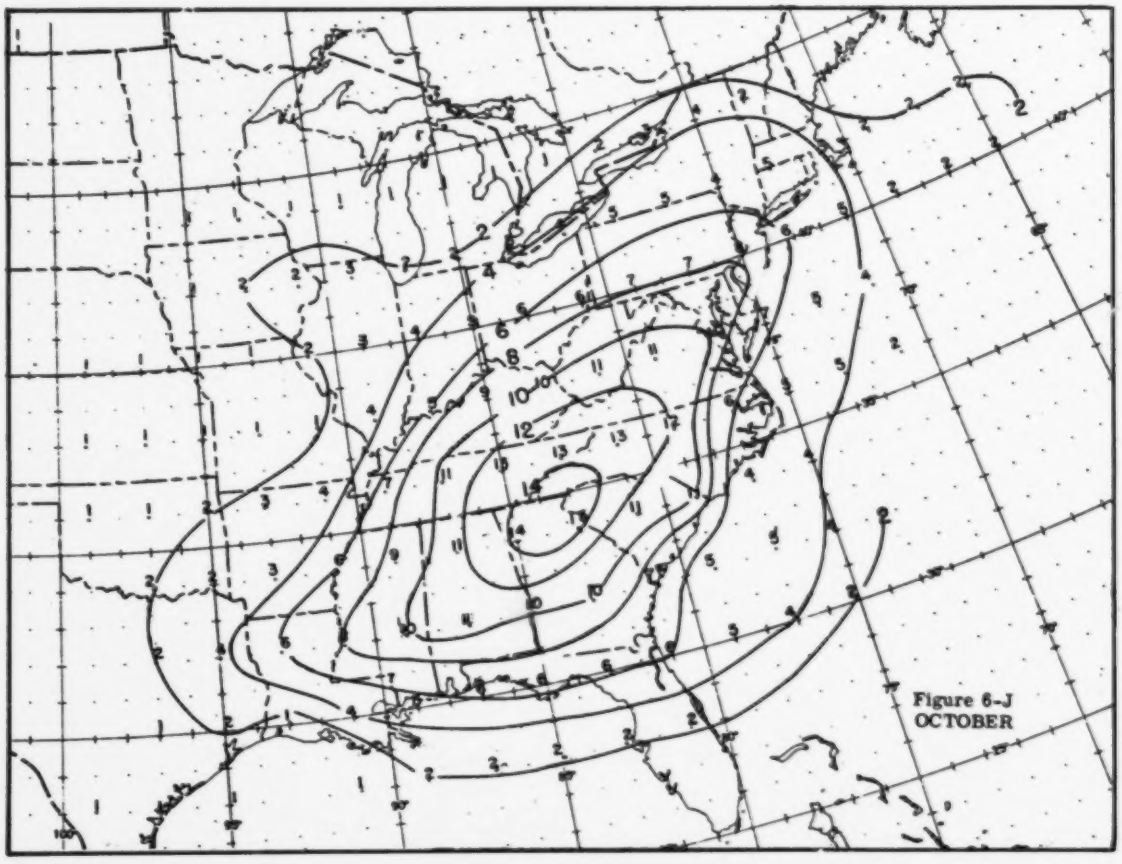

Figure 6-J
OCTOBER

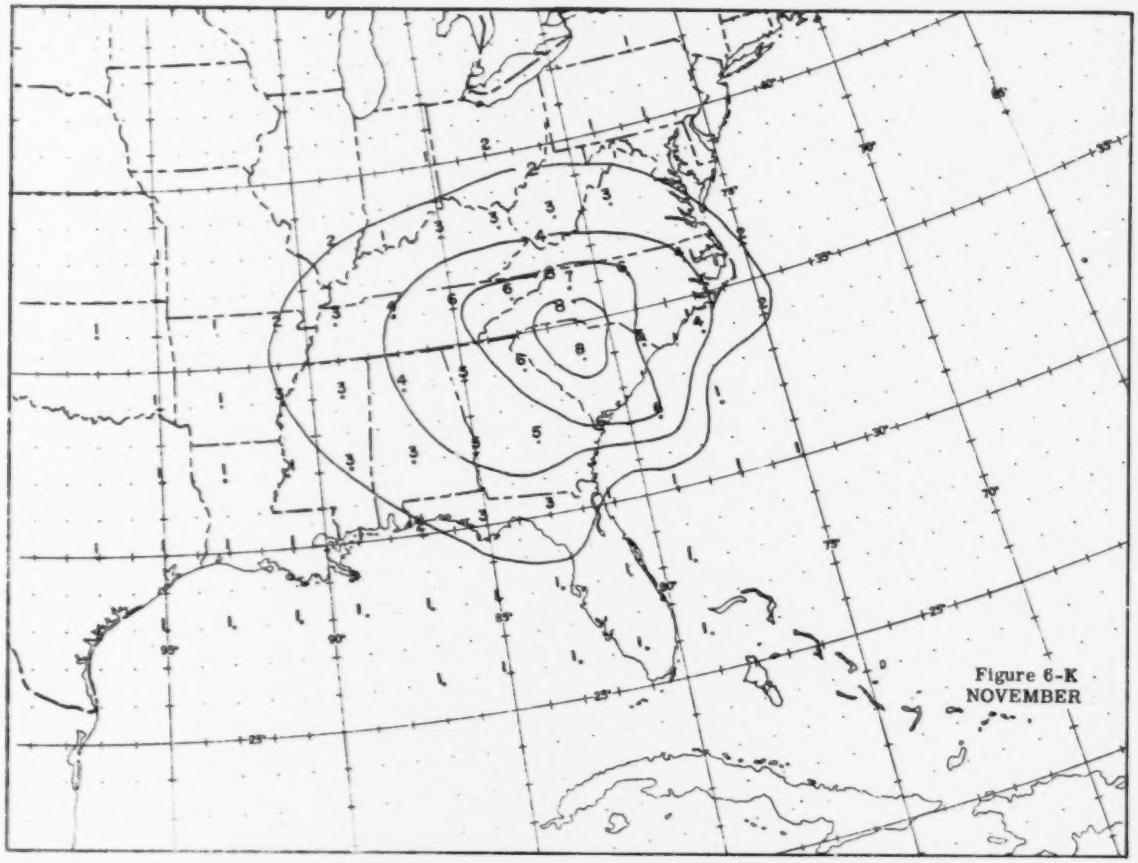

Figure 6-K
NOVEMBER

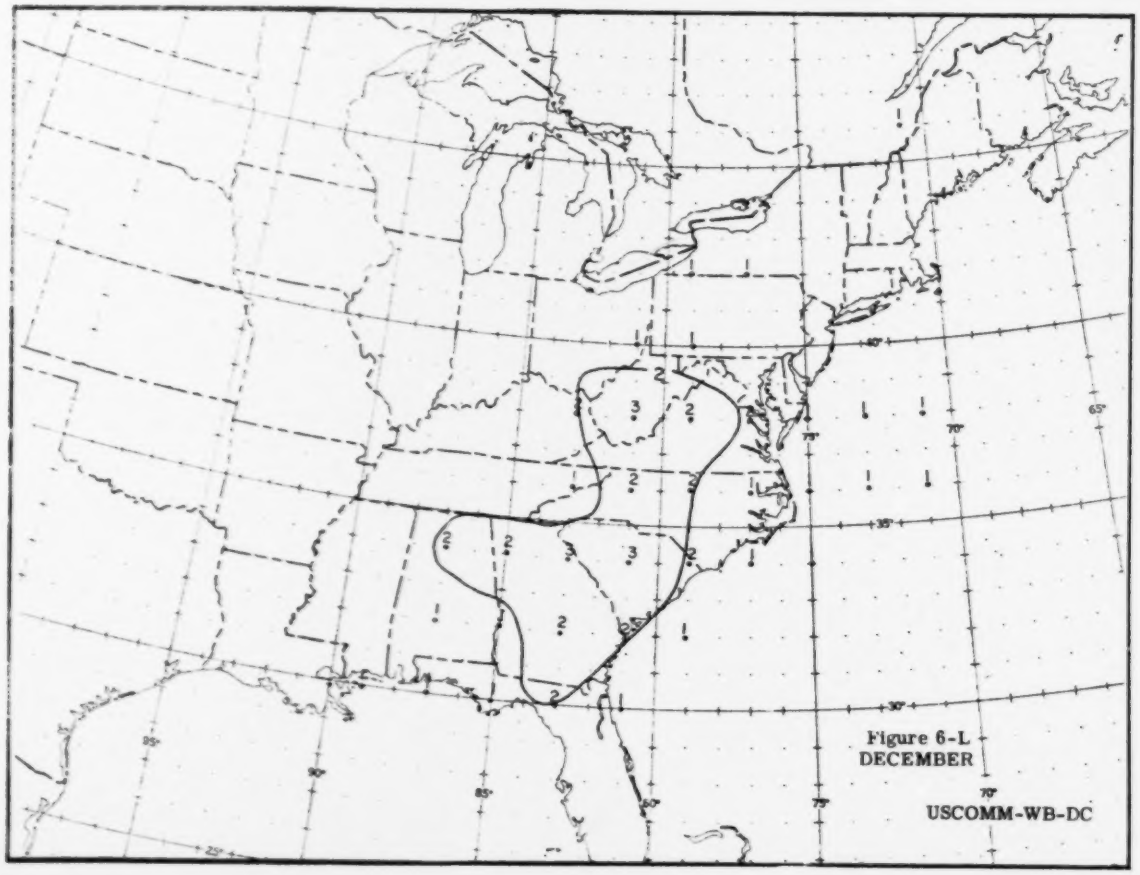

Figure 6-L
DECEMBER

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Table I. Stagnation Cases in the United States, East of the Rocky Mountains, 1936-1956.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1936		23-26			6-11 23-27							21-27	4
1937				17-20				14-17	21-25 S27-01		23-26		5
1938				12-17	17-21			9-12 13-17 19-24		8-13 15-20 25-28			8
1939					4-7	24-28			23-26	4-10	13-18		5
1940				1-5	5-9	2-6			3-7 17-21	10-13 23-28	18-21		8
1941				8-12 14-20 A24-M1	19-22	18-22			19-22 S28-01	12-16			8
1942	11-14			14-17 23-26	A29-M3	M30-J3	18-21		8-11 12-15	7-10			9
1943		17-21		25-29		M30-J5 9-16		3-7 19-26 A29-S2	26-29	3-11 18-21	18-21		11
1944		23-28			A30-M5 12-18	M30-J3	4-7			16-19		4-7	7
1945			16-20 M28-A1			10-13		A27-S1		027-N3			5
1946						22-27	27-30		3-7 13-20 26-29	2-7 14-18 20-25	11-14	3-11	10
1947						20-25		11-18		1-8		1-5	4
1948						1-4	2-6 9-12	21-30	1-8	24-31			6
1949					13-16		23-30			9-12 19-22	6-9		5
1950						6-9 13-20		7-12 22-27	S26-03	16-19 029-N3	6-9		8
1951	27-30		2-5		14-18						20-25 N28-D3		5
1952	D31-J5* 12-18			18-24		23-28		23-28	9-14 S27-01	22-27 030-N2			9
1953	13-16						10-14	A17-S2			030-N3 13-20		5
1954							J26-A1		1-7	1-6 20-27			4
1955			F28-M3 12-19			M31-J6 15-18	1-5	1-6 27-30		9-13	12-17		9
1956				3-6	10-15	13-19 23-27			11-14 26-29	11-16			7
Total	5	3	5	11	12	18	9	16	20	27	12	4	142

* Dec 31 - Jan 5

Table II.
Number of Stagnation Cases for Indicated Period and the Total Number of Days by Month, in the United States, East of the Rocky Mountains, 1936-1956.

Month	Days								Total days
	4	5	6	7	8	9	10	17	
Jan	5	2	2	1					25
Feb	3	2	1						15
Mar	5	3	1	1	1				26
Apr	11	7	4	3	1				59
May	12	9	4	1					62
Jun	18	14	8	5	2				101
Jul	9	5	2	2	1				46
Aug	16	13	10	4	4	2	2	1	190
Sep	20	11	5	4	3				103
Oct	27	18	15	6	5	1			153
Nov	12	6	5	1	1				61
Dec	4	3	2	2	1	1			25
Total	142	93	59	30	19	4	2	1	776

Table III.
Percentage Distribution of Cases of Stagnation for 4 or More Days by Month in the United States, East of the Rocky Mountains.
1936-1956

Month	Day	Percent
	4	
Jan	5	3.5%
Feb	3	2.1
Mar	5	3.5
Apr	11	7.8
May	12	8.5
Jun	18	12.7
Jul	9	6.3
Aug	16	11.3
Sep	20	14.0
Oct	27	19.0
Nov	12	8.5
Dec	4	2.8
Total	142	100.0

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